

POTENTIAL EFFECTS OF RESTORATION ON BIOGEOCHEMICAL FUNCTIONS OF BOTTOMLAND HARDWOOD ECOSYSTEMS

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Abstract—The concept of wetland restoration carries multiple meanings and implications. The scientific usage of the term connotes re-establishment of wetland functions, and often it is the functions, which society deems most valuable, that receive highest focus. Arguably, among key wetland functions, the highest societal value may be linked with the biogeochemical transformation or filtration function, a key contributor to maintenance of water quality. This function requires flow-through hydrology such as that associated with unimpeded riverine forests, and, consequently, its re-establishment is negated by the absence of such hydrology. Consequently, afforestation of former agricultural areas, which were protected from flow-through hydrology, i.e., flooding, by dikes, ditches, etc., cannot be considered restoration in a complete sense unless some semblance of flow-through hydrology is also restored. The term quasi-depressional wetland is suggested as being appropriate for afforested areas where hydrologic restoration is unfeasible.

Rising awareness of the important functions associated with wetlands as well as the extent of historic losses have stimulated societal perceptions of wetlands as rapidly diminishing, yet, highly useful natural resources. Consequently, public support (in principle) for restoration of wetlands is quite high. However, a complex array of socioeconomic factors as well as ecological uncertainties continues to cause confusion in regard to implementation of restoration efforts.

The term ecosystem restoration may vary in connotation depending on the legal, political, scientific, or aesthetic context in which it is used. We suggest that, regardless of context, wetland restoration implies re-establishment of key traits or functions that are valued by individuals and society or both. Thus, the most common way to evaluate particular restoration efforts is to compare functionality between restored systems and a reference, which hopefully represents the predisturbance state.

On former floodplains, afforestation of land previously used for agriculture might be considered as wetland restoration. Regeneration of tree seedlings on areas that were once intensively cultivated may produce several effects that are beneficial to society. These include reduction of sediment export, improvement of wildlife habitat, production of wood and fiber, and enhanced sequestration of carbon. However, despite the value placed on these benefits by society, they are not unique to wetlands.

It is arguable that the most important biogeochemical function that some forest wetlands perform is filtration or removal from waters of sediment, inorganic forms of nutrients, and other substances considered impurities by society. Obviously, this function is predominantly associated with riverine systems, which develop and operate under a

lateral or flow-through type of hydrology so that water continually passes through the wetland filter.

The biogeochemical filtration function of riverine forests is closely linked with the inherently open nature of their geochemical cycles. Nonriverine forest ecosystems as well as those in which contact with their aquatic components has been restricted tend to develop more closed geochemical cycles as they aggrade. The degree of closure is associated with the magnitude of outputs in relation to inputs. Whereas an upland forest may theoretically aggrade to a point where outputs or losses are negligible, i.e., a tight or closed cycle, unaltered riverine forests are somewhat unique in that their geochemical cycles do not approach this degree of closure.

The open-ended geochemical cycles of the riverine forests allow exportation of significant quantities of dissolved organic carbon (DOC), a critical source of energy for aquatic food webs. This biogeochemical function is probably secondary to filtration in terms of societal value but, nonetheless, is quite important.

Consequently, many would agree that riverine forests, apart from those physically separated from their river systems, display two critically important biogeochemical functions: filtration and DOC export. It is also apparent that both functions are intrinsically linked with the flow-through hydrology (and open geochemical cycles) that typifies riverine systems. We suggest that these very simple ideas can be used to examine the degree to which wetlands such as bottomland hardwoods are being restored by particular types of activities.

Afforestation of agricultural fields located on sites historically occupied by riverine forests is currently a widespread activity at the national as well as regional level (Clewell and Lea

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1990; Sharitz 1992; Stanturf and others 1998, 2000). In the Mississippi Delta region of the Southern United States, such afforestation is often referred to as bottomland hardwood restoration (King and Keeland 1999, Stanturf and others 2000b). As previously mentioned, there are several excellent reasons for pursuing such activities. However, the topic at hand dictates that we examine this practice from a biogeochemical standpoint.

In the vast majority of these cases, the practice of agriculture on floodplains necessitated protection from annual flooding in addition to removal of forests. Most often, dikes, levees, or ditches or all were used to physically separate the aquatic and terrestrial components. Obviously, these structures were intended to modify or eliminate the flow-through hydrology that typifies riverine forests. In most cases following agricultural abandonment, socioeconomic factors cause removal of the protective structures to be unfeasible.

An exception is the major restoration effort associated with the Kissimmee River and adjoining lands in Florida (<http://www.saj.usace.army.mil/dp/kissimmee.html>). In that case, approximately 100,000 acres of floodplain are being restored to a state subject to natural flooding. However, as would be expected, restorations at this scale and degree of complexity are very costly, i.e., \$372 million (<http://www.fc.state.fl.us/eog/govdocs/opbenv/saveglades/everglades/html/kissimmee.htm>).

It should be noted that some afforestation areas retain flow through hydrology. These include areas within the batture (unprotected floodplain of the Mississippi River) or those tributaries such as the Yazoo subject to backwater flooding. However, as previously mentioned, restoration of natural,

riverine flooding regimes is rarely feasible. As a result, the aggrading forests on afforested sites cannot exhibit open-ended biogeochemistry and, consequently, will not function as biogeochemical filters or exporters of DOC. This limitation of afforestation activities has been previously recognized (Allen 1997, King and Keeland 1999). Suggested remedies have included plugging drainage ditches or building water control structures on portions of the afforested sites so that controlled flooding can be induced in much the same way that it is applied within greentree reservoirs. On public land such as national wildlife refuges and national forests, relatively large areas have been restored in this fashion as greentree reservoirs, moist soil management units, or permanent water bodies. In addition, it is not uncommon for some flooding to occur on lower lying portions from accumulation of precipitation.

However, it should be recognized that these types of flooding reflect those more commonly associated with depressional wetlands than with riverine. Since it is commonly acknowledged that hydrology represents the dominant controlling process within a wetland (Mitsch and Gosselink 1993), the nature of the hydrology in the restored system is a critical factor in our evaluation of restoration success. Thus, the significance of restoring a former riverine system to quasi-depressional hydrology lies in biogeochemical differences between depressional vs. riverine wetlands.

The chief contrast between riverine vs. depressional hydrology is a predominance of lateral vs. vertical flows respectively (Brown 1990). Consequently, biogeochemical functions are aligned primarily with precipitation, evapotranspiration, and infiltration in basins (fig. 1) as opposed to sheet flow in riverine systems (fig. 2). Lugo and

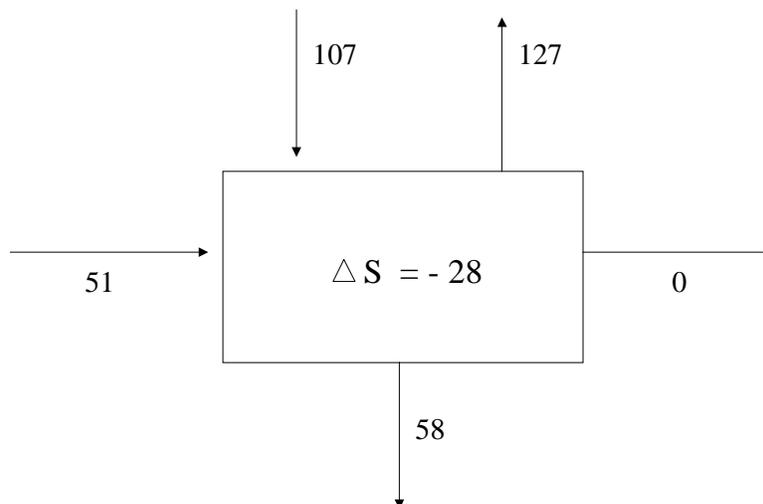


Figure 1—Hydrologic budget for a typical depressional wetland, a cypress dome in Florida. Units are in centimeters per year; depressional wetlands typically have greater inflow than outflow of surface water (Brown 1990).

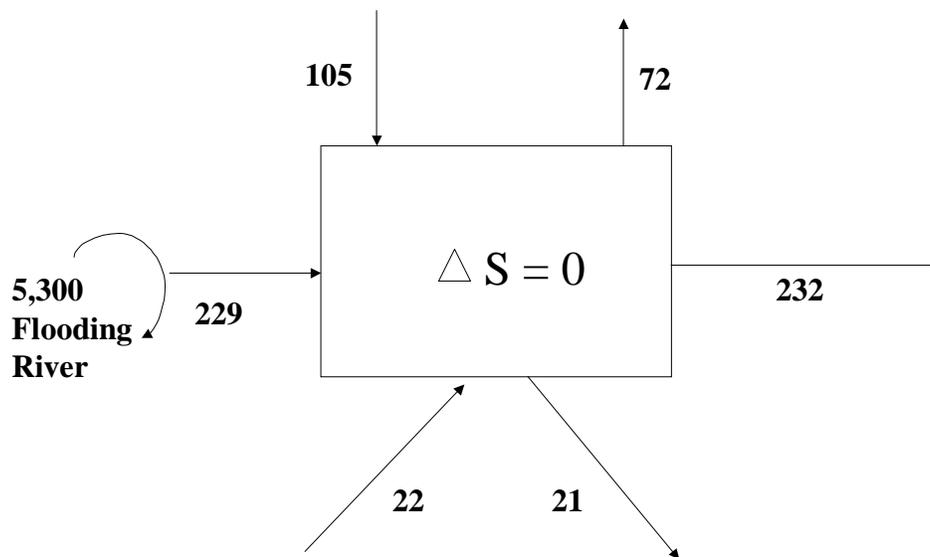


Figure 2—Hydrologic budget for a typical riverine wetland, an alluvial cypress swamp in Illinois. Units are in centimeters per year; riverine wetlands typically exhibit flow-through hydrology (Mitsch and Gosselink 1993).

others (1990) felt that this hydrologic distinction drives differences in terms of how elements are accumulated in the two wetland types as well as which elements would be limiting to NPP; e.g., theoretically P would be more limiting in basins due to the scarcity of vertical input mechanisms.

However, we should also be cautious in assuming that this type of afforestation will result in the formation of typical basin wetlands. There likely will be functional distinctions between a basin wetland, which formed and functions under true basin hydrology, vs. an afforested field, which may occasionally accumulate water. We suggest use of the term quasi-depressional system to indicate this distinction. Because these quasi-depressional systems remain isolated from riverine influences, they contribute little to biogeochemical filtering or to DOC export to aquatic systems.

It is apparent that some basin wetland forests are capable of accumulating nutrients when subjected to elevated inputs (Ewel and Odum 1984). There is also evidence that infiltration export is generally low (Brown 1990), and, consequently, some basins are regarded as nutrient accumulation zones rather than filters or exporters of DOC. However, their lack of hydrologic linkages to major landscapes minimizes their biogeochemical value to society. In particular, the quasi-depressional systems created behind levees or dikes may have even less opportunity to accumulate nutrient inputs because they may exist in a more hydrologically isolated state than true basins.

The U.S. Environmental Protection Agency (EPA) has identified the Yazoo-Mississippi Basin as an area of significant concern for surface and ground water quality.

Although surface water runoff in the Lower Mississippi Alluvial Valley (LMAV) contributes only 20 percent of the nitrate loading implicated in the expansion of the hypoxic zone in the Gulf of Mexico, the EPA is expected to focus significant resources on the LMAV to improve water quality. Policy alternatives under consideration include reducing nitrogen use by 20 to 40 percent and converting agricultural land to forests in an effort to restore and enhance natural denitrification processes (EPA 1999). The assumption is made that restoration (afforestation) of bottomland hardwood forests will reduce nutrient export into the Gulf. This will be true to the extent that a potential source of nutrients will be reduced by changing land use from row crop agriculture to forests (Thornton and others 1998). But the restored system will play at most a small role as a nutrient filter unless it is hydrologically linked to a riverine system. Thus, the greater benefit, in terms of nutrient filtration, would come from conversions within the active floodplain of small rivers throughout the basin of nutrient origin and from buffer strips planted along drainage ways (Castelle and Johnson 2000, Castelle and others 1994). Whereas forested buffer strips may provide advantages to the landowner over grass or herbaceous strips, the relative effectiveness of forest vs. grass buffers on nutrient filtration remains uncertain.

Whereas public support for wetland restoration has traditionally been strong, that support may weaken when local populations are made aware of the implications of true hydrologic restoration within a former floodplain. Such restoration will almost certainly necessitate elimination of land uses that are incompatible with significant flooding, e.g., farming, habitation, etc. Thus, added to the engineering cost of levee removal, etc., are significant compensation expenditures to landowners. In addition, the unpopular

nature of a major taking of private property will also weaken political support for State and Federal appropriations to support the projects. While we neither advocate nor support this approach, the obstacles associated with such an endeavor appear to be significant, and, thus, will make implementation of true riverine restorations difficult to achieve.

In summary, it is recognized that there are many very worthwhile reasons for conversion of former farmland to hardwood forests. However, continued growth in population levels dictates that utilization of landscapes will grow increasingly complex in the years to come. Similarly, it will become critically important that professionals as well as the general public be aware of the specific nature of the changes that are induced (or not induced) by farmland conversion. Only the development and widespread dissemination of that knowledge will protect society from unrealistic expectations, which lead to landscape-level mistakes in natural resource management.

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